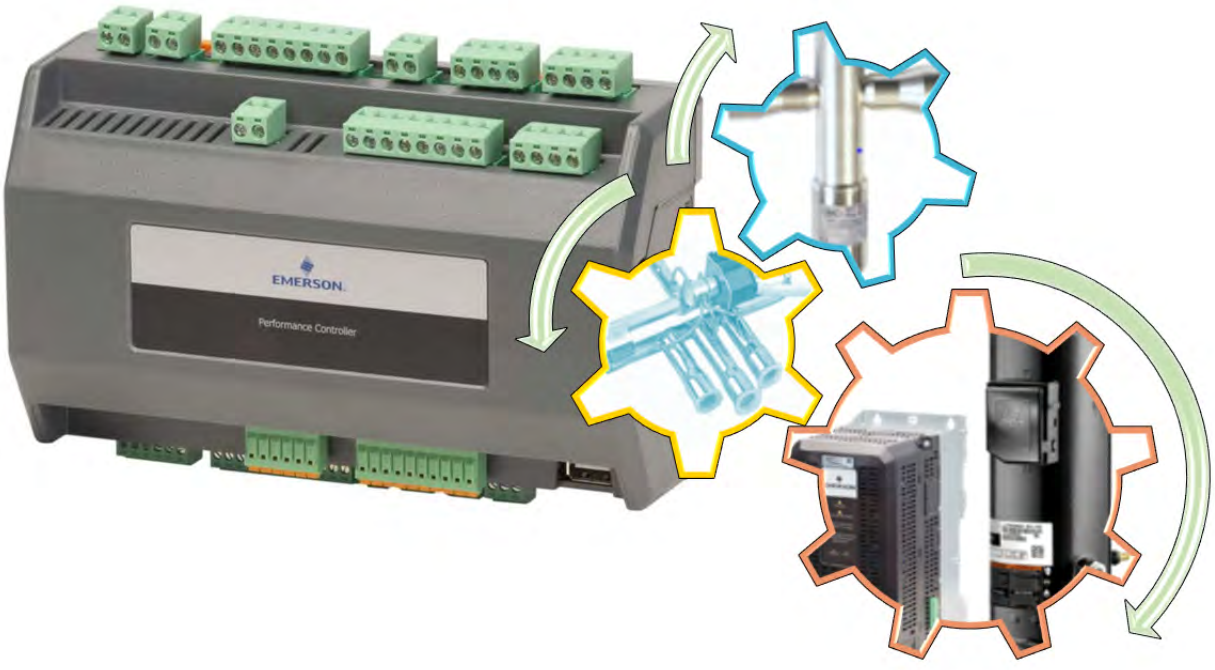
Application Guidelines

PeC Solution Overview for Commercial Comfort Applications



EMERSON.

About these guidelines

The purpose of these guidelines is to provide guidance in the application of the Emerson PeC controller in users' systems. They are intended to answer the questions raised while designing, assembling, starting and operating a system with this product.

Besides the support they provide, the instructions listed herein are also critical for the proper and safe functioning of the system. The performance and reliability of the system may be impacted if the product is not used according to these guidelines or is misused.

These guidelines cover stationary applications only. For mobile applications, please contact the Application Engineering department at Emerson as other considerations may apply.

1 Safety instructions

Emerson PeC controllers are manufactured according to the latest European safety standards. Particular emphasis has been placed on the user's safety.

The PeC controllers are intended for installation in systems in accordance with the European Machinery Directive MD 2006/42/EC, the Low Voltage Directive LVD 2014/35/EU and the Electromagnetic Compatibility Directive EMC 2014/30/EU. They may be put to service only if they have been installed in these systems according to instructions and conform to the corresponding provisions of legislation. For relevant standards please refer to the Manufacturer's Declaration, available on request or at www.climate.emerson.com/en-gb.

These guidelines form part of the product and must always be kept near the controller for easy and quick reference. They should be retained throughout the lifetime of the controller.

You are strongly advised to follow these safety instructions.

1.1 Icon explanation

	**WARNING** This icon alerts the user of important instructions to avoid personal injury and material damage.		**CAUTION** This icon alerts the user of instructions to avoid property damage and possible personal injury.
	**WARNING** **High voltage!** This icon alerts the user of non-insulated "dangerous voltage" within the product area that is sufficiently high to constitute a risk of electric shock to persons.		**IMPORTANT** This icon alerts the user of important operating and maintenance or assistance instructions.
	**Danger of explosive atmosphere** This icon indicates a risk of explosive atmosphere.	***NOTE***	This word indicates a recommendation for easier operation.

1.2 Safety statements

- **This product can only be used for purposes specified by the manufacturer.**
- **This product is designed to be used in HVAC/R systems and can only be installed, operated or maintained by qualified electrical personnel with additional system-related expertise. Please immediately contact the manufacturer for support if the user is uncertain with any safety-related issue.**
- **Electrical connections must be made by qualified electrical personnel with additional system-related expertise.**
- **All valid standards and local electrical regulations for connecting electrical and refrigeration equipment must be observed.**
- **The national legislation and regulations regarding personnel protection must be observed.**

Use personal safety equipment. Safety goggles, gloves, protective clothing, safety boots and hard hats should be worn where necessary.

1.3 General warnings

WARNING
Conductor cables! Electrical shock hazard! This product operates at hazardous voltages which can cause severe personal injury or equipment damage. Extreme care and precautions must be taken when handling the product. Electrical connections must be made by qualified electrical personnel.
Use a grounded system only. Moulded electrical plugs must be used in all applications. Refer to original equipment wiring diagrams.
Do not operate system before all cable connections are completed. Disconnect all voltages from system before installation or service. Allow drive components to electrically discharge for a minimum of two minutes before servicing.

WARNING
Conductor cables! Electrical shock hazard! The controller must always be inserted inside an electrical panel that can only be accessed by authorised personnel. The keyboard must be the only part that can be reached. The device must never be hand-held while being used.

CAUTION
The controller cannot be used as a safety device. Verify the limits of application before using the device.

IMPORTANT
Transit damage! Controller disfunction! Use original packaging.

1.4 Use with flammable refrigerants

WARNING
The PeC controller is not designed or qualified based on the ATEX directive! The PeC controller fulfils the requirements of the mentioned system standard with the usage of flammable refrigerants.

Usage with flammable refrigerants is limited to systems which are based on the IEC 60335-2-40 standard. For systems using flammable refrigerants A2L and A3 the following points must be considered:

- The controller mounting area must be in **Zone 2** or outside any ATEX zone and in line with "**Pollution Degree 2**" classification.
- No airstream guided over the electronics.
- No condensation under normal operation.
- The IP class of the controller mounting area must be in line with the system standard.

1.5 General recommendations

The customer shall bear full responsibility and risk for product configuration in order to achieve the results pertaining to installation and/or final equipment/system. Upon customer's request and following a specific agreement, Emerson. may be present during the start-up of the final machine/application, as a consultant. However, under no circumstances can Emerson be held responsible for the correct operation of the final equipment/system.

Since Emerson products form part of a very high level of technology, a qualification/configuration/ programming/commissioning stage is required to use them as best as possible. Otherwise, these products may malfunction, and Emerson cannot be held responsible.

It is good practice to bear the following in mind for all Emerson products:

- Prevent the electronic circuits from getting wet as contact made with water, humidity or any other type of liquid can damage them. Comply with the temperature and humidity limits specified in the guidelines in order to store the product correctly.
- The device must not be installed in particularly hot environments as high temperatures can cause damage, eg, to electronic circuits and/or plastic components forming part of the casing.

Comply with the temperature and humidity limits specified in the guidelines in order to store the product correctly.

- Under no circumstances is the device to be opened – the user does not require the internal components. Please contact qualified service personnel for any assistance.
- Prevent the device from being dropped, knocked or shaken as either can cause irreparable damage.
- Do not clean the device with corrosive chemical products, solvents or aggressive detergents.
- The device must not be used in applications that differ from those specified in these guidelines.

1.6 Communication with Application Engineering and Development teams

When communicating with Application Engineering and/or development teams at Emerson during the development and testing phases of programs using the PeC, please include:

1. log file
2. description file
3. configuration file

These will help them give you more precise and complete answers to your questions.

2 Product description

2.1 General information about the Emerson PeC controller

The PeC (Performance Controller) controller has been specifically developed for Copeland™ scroll compressors using R410A and R32 refrigerants in heating and cooling applications such as reversible heat pumps, in both air-to-water and brine-to-water configurations.

PeC was developed to run and protect the refrigerant cycle with low control effort for the system controller but also to provide detailed information around the refrigerant cycle.

Figure 1: PeC external view

Figure 2: Internal view

The external dimensions of the PeC controller are 185 x 130 x 60 mm.

Figure 3: Top side view

Figure 4: Bottom side view

2.2 Refrigerants

The PeC controller operates with refrigerant systems using:

- R410A
- R32

2.3 Available PeC configurations

The following tables show the hardware and software capabilities with PeC C100 and C200.

PeC C100	Circuit 1				
	VS compressor + EV3 drive	Fixed speed	Temperature probe min-max	Pressure	EXV (bipolar)
	1-3 (1 can be a variable speed)		5-7	2	1

Table 1

PeC C200	Circuit 1					Circuit 2				
	VS compressor + EV3 drive	Fixed speed	Temperature .probe min-max	Pressure	EXV (bipolar)	VS compressor + EV3 drive	Fixed speed	Temperature . Probe min-max	Pressure	EXV (bipolar)
	1-3 (1 can be a variable speed)		5-7	2	1	0	0-3	4-6	2	1

Table 2

***NOTE:* The PeC factory default is unconfigured (-1) so configuration is needed. Invalid or unconfigured compressor package selection will cause an alarm.**

2.4 Main components and parts

For components and parts ordering please contact the Application Engineering or Sales Department at Emerson.

2.4.1 Supported compressor range

The PeC controller has been specifically developed for Copeland Scroll variable-speed compressors using R410A and R32 refrigerants. It is currently qualified for the following ranges:

	R32	
	Fixed-speed compressor	**Variable-speed compressor**
	YP137	YPV066
	YP154	YPV096
	YP182	
	YP232	
	YP292	

Table 3: Qualified compressors for use with R32

	R410A	
	Fixed-speed compressor	**Variable-speed compressor**
	ZP104	ZPV066
	ZP122	ZPV096
	ZP154	
	ZP182	
	ZP232	
	ZP292	

Table 4: Qualified compressors for use with R410A

***NOTE:* Additional fixed-speed compressors may be supported based on customer request.**

2.4.2 Supported variable speed drive

	EV3150	EV3185	Compatible compressor model
	1		YPV066
	1		ZPV066
		1	YPV096
		1	ZPV096

Table 5: Compatible compressor models

NOTE: **The Emerson EV3 inverter drive is compliant with CAT 3 of EMC homologations.**

2.4.3 PeC accessories

Plug-in connector

	PeC C100	Screw terminals and/or cage clamp female connectors
	PeC C200	Screw terminals and/or cage clamp female connectors

Table 6

USB adapter

	XJ485-USB converter
	Cable XJ485-USB converter

Table 7

2.4.4 Supported electronic expansion valve range

	Alco EX4
	Alco EX5
	Alco EX6
EXV-M30 (wires)	3.0 m

Table 8: Qualified expansion valves

NOTE: **Additional expansion valves may be supported based on customer request.**

2.4.5 Supported pressure transmitters

	Alco PT5N-7 (7 bar max)	Low side
	Alco PT5N-10 (10 bar max)	
	Alco PT5N-18 (18 bar max)	
	Alco PT5N-30 (30 bar max)	High side
	Alco PT5N-50 (50 bar max)	
Cable for PT5N	PT4-M30	3.0 m

Table 9: Qualified pressure transmitters

NOTE: **Additional pressure transducers may be supported based on customer request.**

2.4.6 Supported temperature sensors

	TP1 series
	100K (high temperature) (for future use)

Table 10: Qualified temperature sensors

NOTE: **Additional temperature sensors may be supported based on customer request.**

2.5 PeC system functionalities

The PeC controller controls and manages the refrigerant system comprising the Copeland Scroll variable-speed compressor (ZPV066 or ZPV096 & YPV066 or YPV096), the drive, the electronic expansion valves (EX range) and the 2- or 4-way valve. It is not a main system controller: it does not control or manage the full unit (chiller / heat pump / others).

The OEM system controller and the PeC communicate via Modbus serial communication, in order to exchange the fundamental parameters and information to provide an optimised combined control of compressor and expansion devices for maximum performance and reliability.

Table 11 below gives an overview of the PeC features and benefits.

PeC	Features	Benefits
Smart refrigerant circuit management	▪ Variable speed & fixed speed ▪ Tandem/Trio capacity management ▪ Smart superheat control & EXV management ▪ Dynamic compressor operating maps management ▪ Reverse cycle management	High efficiency & reduced time-to-market
Protection & diagnostics	▪ Active compressor envelope protection ▪ Active floodback protection ▪ Oil recovery management ▪ Performance monitoring	Improved protection & increased reliability
Communication	▪ RS485 Modbus OR analog interface communication with system controller ▪ Pre-programmed Modbus communication with CSD100 and alarms/parameters transfer	Modularity

Table 11

2.6 System configuration

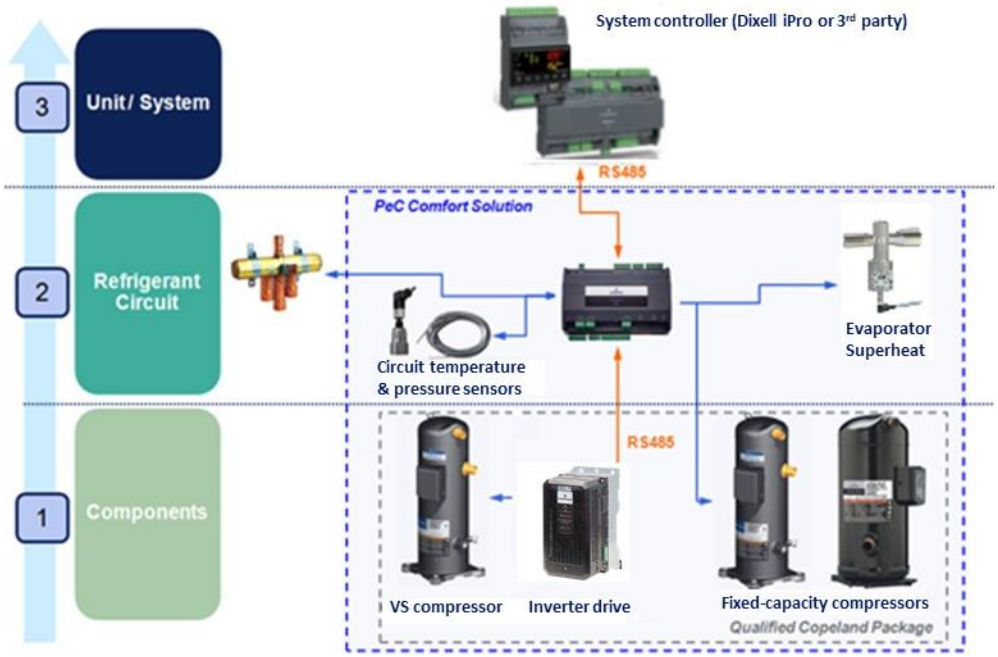


Figure 5

3 Hardware configuration

3.1 PeC Hardware configuration options

The controller board owns digital inputs and outputs that can provide customized use to the OEM. Configuration can be set via Modbus using "Configuration Parameters".

Factory default of digital inputs & outputs	Description	Type
DI1	Input for high-pressure switch signal	Fixed function
DI2	*Input for demand On/Off selection*	*Future use*
DI3	*Input for heating or cooling mode selection*	*Future use*
DO1	Relay for switching 2 or 4-way valve	Fixed function
DO2	Relay for fixed-speed compressor start/stop	Fixed function
DO3	Relay for fixed-speed compressor start/stop	Fixed function
DO4	Relay for fixed-speed compressor start/stop	See below

Table 12

Configuration parameter options on DO1:

Register [94] if Defrost is enabled

0 = Cooling open circuit, heating closed circuit

1 = Cooling closed circuit, heating open circuit

Configuration parameter options on DO4:

Register [150] if compressors 1,3 installed (refer to index 86 bit 3) then relay can be used to indicate PeC status

0 = Alarm negative logic (Alarm = Relay contact open)

1 = Alarm positive logic (Alarm = Relay contact closed)

2 = Drive active positive logic (speed <> = 0 relay closed)

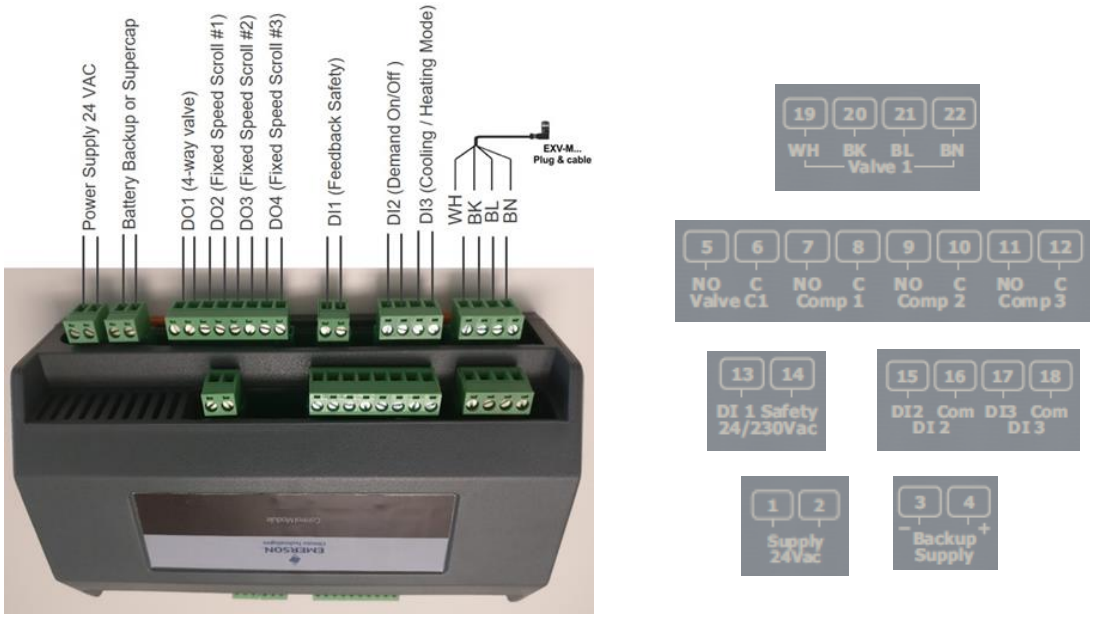


Figure 6: PeC controller top side – Power supply, digital outputs & inputs & EXV connections

NOTE: **For more information please refer to Application Guidelines AGL_Sol_PEC_01 "PeC Solution Controllers for commercial Comfort Applications – PeC C100 & PeC C200" or contact your local Application Engineering representative at Emerson.**

3.2 Examples of application

3.2.1 Monoblock air-to-water chiller system scheme with variable-speed & fixed-speed compressors and 1 electronic expansion valve

The schematic in **Figure 7** shows an air-to-water chiller designed for cooling applications.

PeC controller				
I/O	**Type**	**Function**	**Comments**	
P1	PT5N-7-10-18	Suction pressure for superheat (SH) control, high SH protection and envelope management	Configurable	Mandatory
P2	PT5N -30-50	Discharge pressure for envelope management	Configurable	Mandatory
T1	TP1	Evaporator outlet gas temperature for SH control and high SH protection	Configurable	Optional
T2	TP1	Compressor suction gas temperature for SH control and high SH protection	Configurable	Mandatory
T3	TP1	Ambient temperature	Configurable	Mandatory
T4	TP1	Liquid temperature before main EXV for energy counter function & EXV management	Configurable	Mandatory
T5	TP1	Variable-speed compressor discharge temperature	Configurable	Mandatory
T6	TP1	Fixed-speed compressor discharge temperature	Configurable	Mandatory
T7	TP1	Fixed-speed compressor discharge temperature	Configurable	Mandatory
	24 VAC	Power supply	Fixed	
	24 VDC	Supercap XEC mono valve	Optional	
DO1	Relay	4-way	Fixed	Not needed
DO2	Relay	Fixed-speed compressor command #1	Configurable	
DO3	Relay	Fixed-speed compressor command #2	Configurable	
DO4	Relay	Fixed-speed compressor command #3 ➔ indicates if the drive is running or not	Configurable	
DI1	Digital input	Feedback safety	Fixed	
DI2	Digital input	Not used	State readable by Modbus	Optional
DI3	Digital input	Not used	State readable by Modbus	Optional
EXV/BIP	Stepper out - bipolar	EXV control	Fixed	
An.In.	0-10 V analog input	Not used	State readable by Modbus	Optional
Bus Inverter	Modbus RS485	Communication with EV3 inverter	Fixed	
Bus Ctrl	Modbus RS485	Communication with system controller	Fixed	
Bus Slave	Modbus RS485	Modbus slave (may be used for monitoring and/or flashing)	Fixed	

Table 13

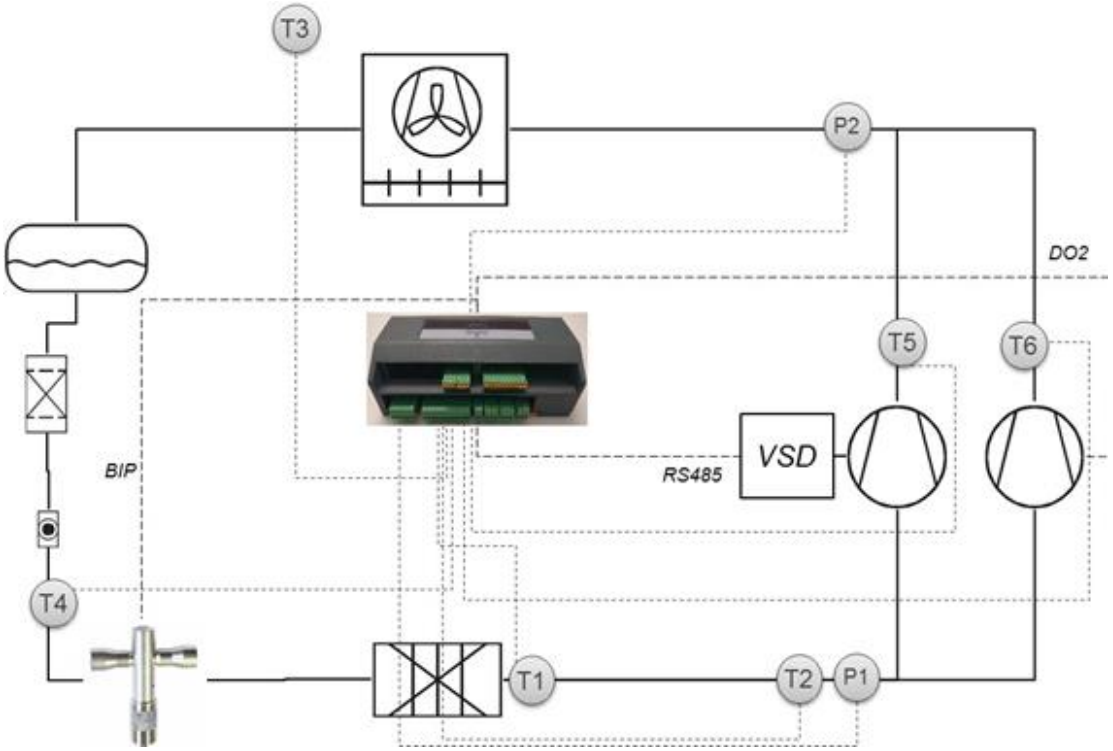


Figure 7: Air-to-water chiller for cooling application

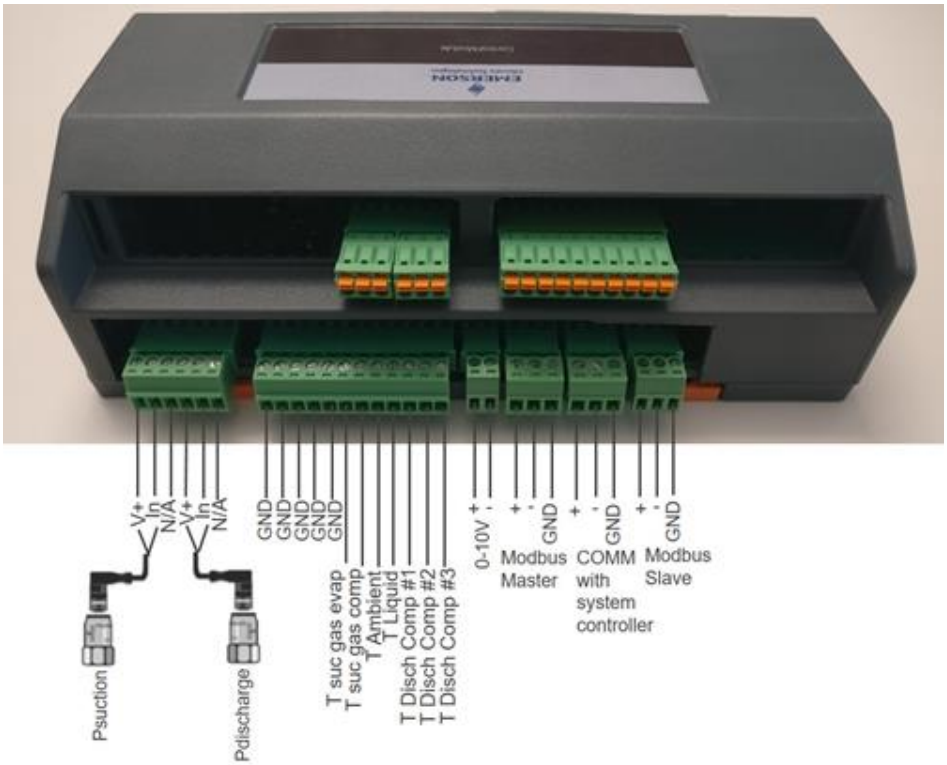


Figure 8: PeC C100 bottom side – Digital inputs, Modbus communication, pressure and temperature inputs

NOTE: **For more information please refer to Application Guidelines AGL_Sol_PEC_01 "PeC Solution Controllers for commercial Comfort Applications – PeC C100 & PeC C200" or contact your local Application Engineering representative at Emerson.**

3.2.2 *Monoblock air-to-water reversible heat pump system scheme with variable-speed & fixed-speed compressors and 1 electronic expansion valve*

The schematic in **Figure 9** shows an air-to-water reversible chiller/heat pump with the ability for reverse cycling for defrost and heating modes. The main expansion valve, 4-way valve and compressors are controlled by PeC.

PeC controller				
I/O	**Type**	**Function**	**Comments**	
P1	PT5N-7-1018	Suction pressure for superheat (SH) control, high SH protection and envelope management	Configurable	Mandatory
P2	PT5N -30-50	Discharge pressure for envelope management	Configurable	Mandatory
T1	TP1	Evaporator outlet gas temperature for SH control and high SH protection	Configurable	Optional
T2	TP1	Compressor suction gas temperature for SH control and high SH protection	Configurable	Mandatory
T3	TP1	Ambient temperature	Configurable	Mandatory
T4	TP1	Liquid temperature before main EXV for energy counter function & EXV management	Configurable	Mandatory
T5	TP1	Variable-speed compressor discharge temperature	Configurable	Mandatory
T6	TP1	Fixed-speed compressor discharge temperature	Configurable	Mandatory
T7	TP1	Fixed-speed compressor discharge temperature	Configurable	Mandatory
P1	24 VAC	Power supply	Fixed	
P2	24 VDC	Supercap XEC mono valve	Optional	
DO1	Relay	4-way	Configurable	Not needed
DO2	Relay	Fixed-speed compressor command #1	Fixed	
DO3	Relay	Fixed-speed compressor command #2	Fixed	
DO4	Relay	Fixed-speed compressor command #3 ➔ indicates if the drive is running or not	Configurable	
DI1	Digital Input	Feedback safety	Fixed	
DI2	Digital Input	Not used	Fixed	Optional
DI3	Digital Input	Not used	Fixed	Optional
EXV/BIP	Stepper out - bipolar	EXV control	Fixed	
An.In.	0-10 V analog input	Not used	Fixed	Optional
Bus Inverter	Modbus RS485	Communication with EV3 inverter	Fixed	
Bus Ctrl	Modbus RS485	Communication with system controller	Fixed	
Bus Slave	Modbus RS485	Modbus slave (may be used for monitoring and/or flashing)	Fixed	

Table 14

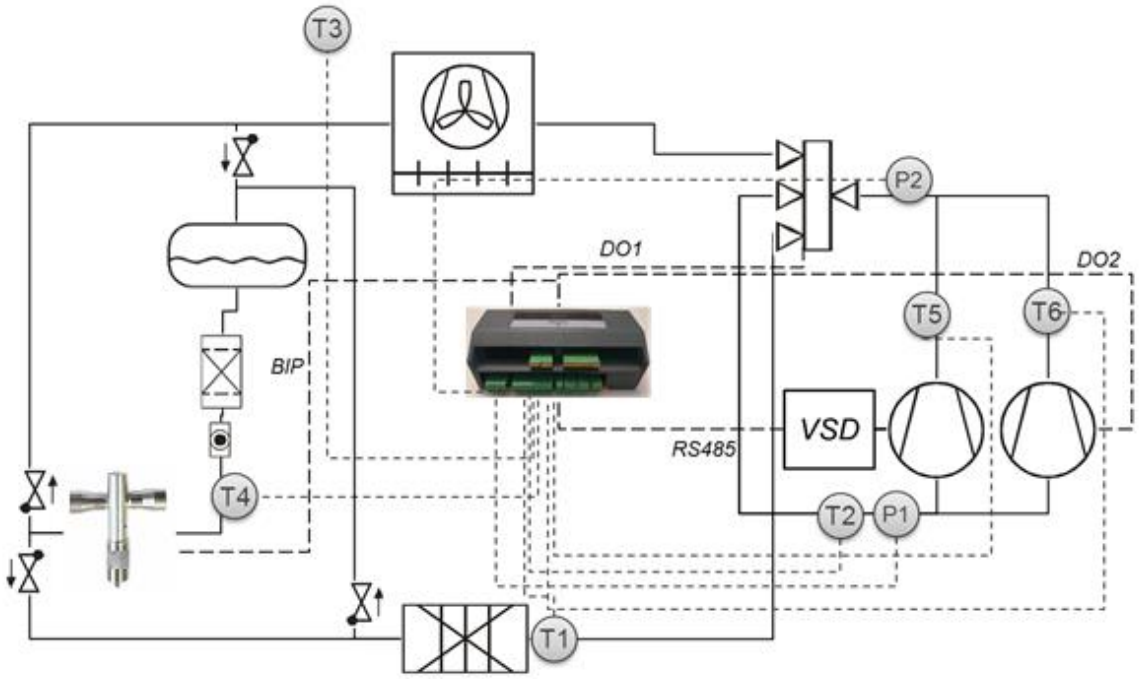


Figure 9: Air-to-water reversible chiller/heat pump

3.3 DLT sensor installation

The DLT sensor assembly improves the accuracy and response time of the temperature management.

The high-pressure safety input was designed to fulfill the requirements of standard EN 378.

Please follow the recommendations below for sensor assembly:

- The temperature sensor has to be installed along the straight or bended pipe at a distance of 120 mm from the compressor shell.
- The discharge pipe including the sensor must be insulated to reduce the impact of ambient temperature.
- Use thermal compound to improve heat transfer to the sensor. The thermal compound must be approved for maximum system operating temperatures (usually 150 °C for R32).
- Protect the sensor from being moved or removed from its position by transport, vibration or any other incident.
- The sensor must be installed in a copper sleeve to improve response time and to reduce setoff. The copper sleeve must be brazed on the surface of the discharge pipe. Use thermal compound to improve the heat transfer from the sleeve to the sensor.

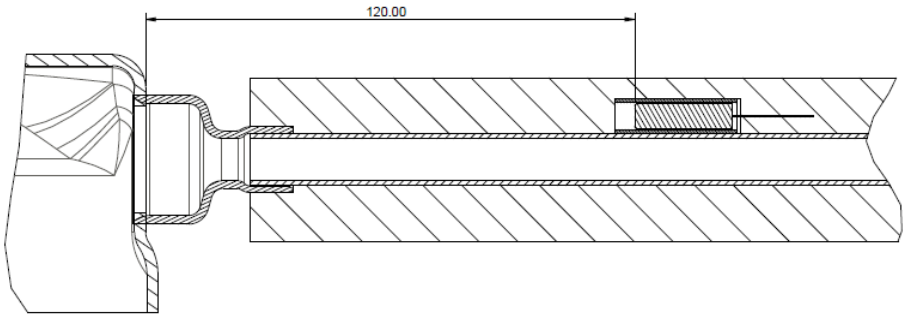


Figure 10: Discharge temperature sensor mounting

4 OEM control strategy on PeC

4.1 System controller with Modbus communication

<table>
<tr><td colspan="6">OEM system controller with Modbus RS485 RTU</td><td>System controller or separate hardware</td></tr>
<tr><td colspan="6">Bus</td><td>Digital I/O</td></tr>
<tr><td>↓</td><td>↓</td><td>↓</td><td>↑……↑</td><td>↑……↑</td><td>↓……↓</td><td>↓↑↑↑</td></tr>
<tr><td>Operating mode
Heating/Cooling
Standby/Off</td><td>Capacity</td><td>Defrost
Start/Stop</td><td>Refrigerant cycle info
Measured & calculated values</td><td>Alarms and warnings
Hardware & software</td><td>Manual control
3 EXV’s & speed & 2 relays
4/2-way valve</td><td>Digital
Switches/Input</td></tr>
<tr><td>↓</td><td>↓</td><td>↓</td><td>↑……↑</td><td>↑……↑</td><td>↓……↓</td><td>↓↑↑↑</td></tr>
<tr><td colspan="6">Bus</td><td>Digital I/O</td></tr>
<tr><td colspan="7">PeC</td></tr>
</table>

Table 15

The PeC was developed to run and protect the refrigerant cycle with low control effort for the system controller but also to provide detailed information around the refrigerant cycle.

The system controller has to provide operating mode and capacity request to run the system.

- PeC operating modes can be Off, Heating, Cooling, Standby or Manual.
- Modbus communication also gives the possibility of enhanced use of all PeC functions shown above.
- Accessories (pumps, fan, etc.) have to be controlled directly by the OEM controller to ensure problem-free conditions for running the refrigerant cycle, eg, water flow on condenser around compressor activity.

The OEM is responsible for developing a mitigation strategy in response to the occurrence of alarms and warnings on the PeC.

There are different alarm conditions: "Alarm", "Warning" and "Alarm State".

Alarms and warnings may not lead to direct system shutdown. The system controller can monitor these and take preventive action with the capacity request in order to avoid system shutdown by an "Alarm State". The occurrence of an "Alarm State" will force immediate system shutdown.

When not acting on the PeC during an "Alarm State" phase, the PeC will recover, if possible, after a recommended waiting phase (Alarm Pause).

The OEM has to consider the best response to specified alarms, eg, continue to activate the system or let the system run, lock the system to protect it against damage, etc.

An advantage of Modbus communication is that it provides the full PeC functionality such as:

1) Operation control
   - Gives precise control on operating mode and capacity request given %.
2) Monitoring all sensor values and system status
   - Gives opportunity to use these data for OEM processing the system by the system controller and for data logging. This provides valuable information to analyse the system operation.
3) Explicit warning and alarm information
   - The OEM controller can get explicit fault and warning information for preventive actions on the system, as well for service and maintenance.
4) Manual control options
   - For customized individual control strategy, the OEM controller can take control on the compressor speed, the EXV’s and the 4-way valve instead of PeC internal control function.
5) Additional hardware functionality
   - 1 Digital input + 2 potential free relays can be used by the system controller via Modbus or internal pre-defined function.

4.2 OEM capacity demand strategy

The OEM controller should adapt the capacity demand signal to variable speed operation. Common P, PI or PID control strategy should be used to avoid strong setpoint exceeding. This will enhance the system efficiency and reduce useless high speeds, temperatures and sound on the system. An optimal strategy has to be figured out via OEM system qualification process.

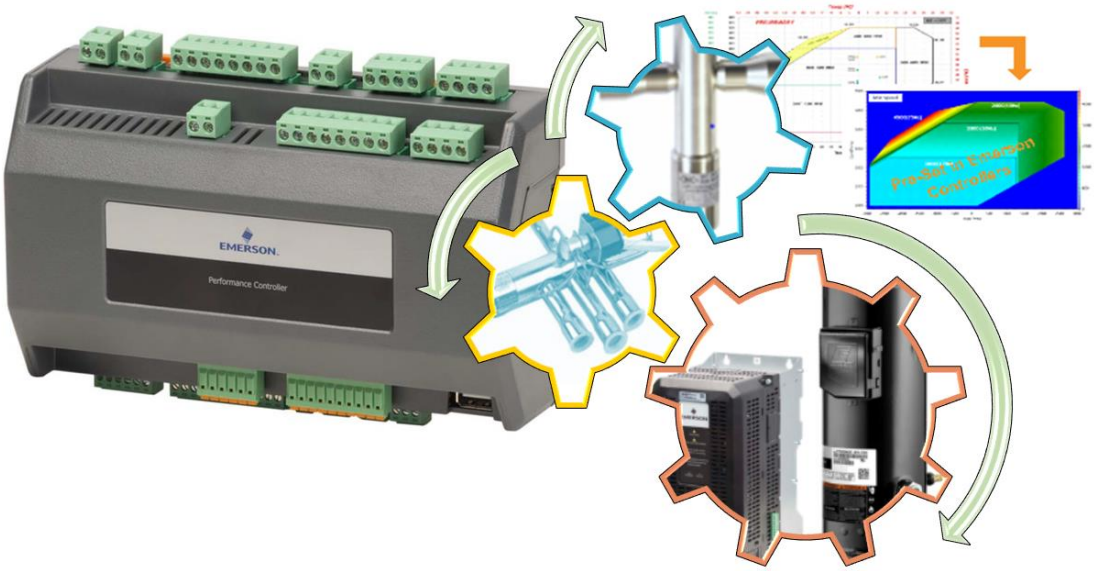


Figure 11

4.3 System controller with analog 0-10 V demand signal + 1 digital signal

Currently unused –Option available in future.

5 PeC functionalities

5.1 State machine matrix

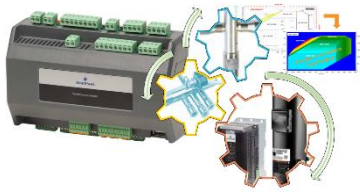
State machine	Loads to manage		
	**EXV** 	**Compressor pack** 	**4-way valve** 
Off	After shutdown all valves are closed, the 4-way valve switches to cooling position		
Start-up	Normal start-up with predefined opening (function of ambient temperature)	Normal start-up with predefined speed and duration	Swappable
			Heating or cooling active
Shutdown	Combination of suction pressure and compressor speed	The compressor speed is reduced and the valve is closing.	
Standby		Stator heater	
Cooling	Normal operation (dynamic setpoint graph)	Normal capacity matching	
	Low superheat operation (IP-sensitive)	Exceptions (protections, prevention)	
	Floodback operation	Exceptions (protections, prevention)	
Heating	Normal operation (dynamic setpoint graph)	Normal capacity matching	
	Discharge temperature protection		
	Floodback operation		
Transition to cooling / defrost	With unit stop: close valves in relation with capacity	With unit stop: shut down all compressors regularly	With unit stop: wait for pressure band to swap
	Without unit stop: proceed to cooling start-up opening	Without unit stop: ramp down to defined capacity on each circuit	Without unit stop: wait for defined capacity to swap
			Low delta pressure protection
Transition to heating	With unit stop: close valves in relation with capacity	With unit stop: shut down all compressors regularly	With unit stop: wait for pressure band to swap
	Without unit stop: proceed to cooling start-up opening	Without unit stop: ramp down to defined capacity on each circuit	Without unit stop: wait for defined capacity to swap
			Low delta pressure protection
Defrost	Suction pressure regulation	Suction pressure regulated capacity band	
Manual	Full manual mode	Full manual mode	Full manual mode
Emergency shutdown	Valve closing by capacity	Fast capacity shutdown	No action
Alarm	Valve closing by capacity	Fast capacity shutdown	No action

Table 16

The application is governed by a state machine of which the various states can be described as follows:

- **Off:** The compressor shutdown procedure is executed. After shutdown, all valves are closed, the 4-way valve switches to cooling position.
  The stator heater function is active for both variable and fixed-speed scrolls.
- **Shutdown:** The compressor speed is reduced and the valve is closing.
- **Standby:** The compressor shutdown procedure is executed. After shutdown all valves are closed and the 4-way valve switches to cooling position.
  The stator heater function is active.
- **Cooling:** The compressor is running, the expansion valve is active and the 4-way valve is in cooling position.
- **Heating:** The compressor is running, the expansion valve is active and the 4-way valve is in heating position.
- **Alarm:** The unit has encountered a problem and stopped. When the PeC enters this state, it shadows and clears the alarms. To avoid immediate restart, the unit is moved into waiting state for a configurable amount of time.
- **Transit cooling:** The normal shutdown procedure is applied to switch off the compressors then restart the system to cooling mode.
- **Transit heating:** The normal shutdown procedure is applied to switch off the compressors then restart the system to heating mode.
- **Defrost:** The compressor is running, the expansion valve is active, the 4-way valve is in cooling position.
- **Waiting:** The unit is in delayed restart after an alarm occurred during operating mode.
- **Manual:** The user takes control of every component individually.
- **Compressor start:** The unit has a heating request but the 4-way valve is in cooling mode, so the unit starts in cooling mode to build up the necessary pressure to switch the 4-way valve. Duration: 10 seconds at 2700 rpm.

5.2 Functionalities

5.2.1 Smart compressor operating map management

The operating envelopes of the variable-speed Scroll (VSS) are stored in the controller.

Based on measurements of suction and discharge pressures the possible speed range is calculated for every operating point. Protection algorithms prevent the operating point to leave the operating map by acting on compressor speed and expansion valve opening. Envelope alarm limits are defined in order to avoid operation out of the envelope.

Additional fallback protection is implemented as safety software function in the drive. Torque and discharge temperature limitation are the major protective features.

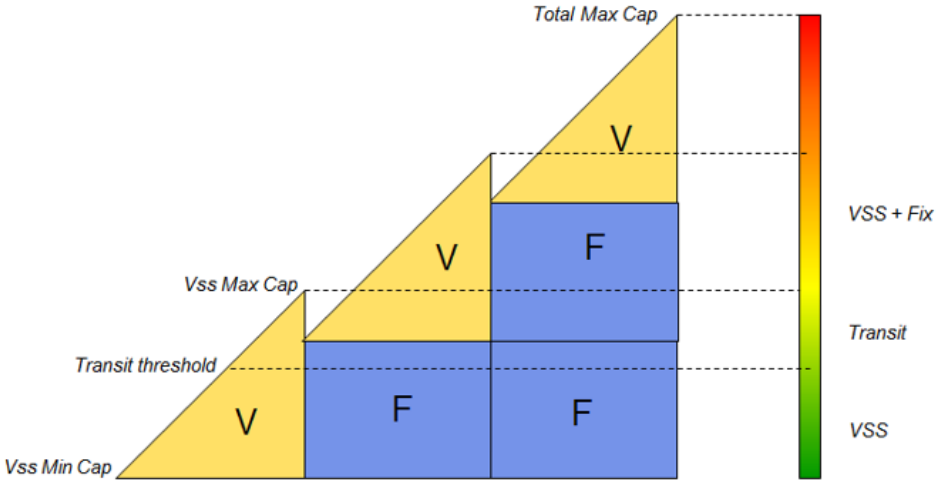


Figure 12

5.2.2 DLT limitation control function with wet suction control

The PeC will monitor the discharge line temperature. In case the high DLT area is entered, superheat control will change into Discharge Temperature Protection control. The smart logic on the EXV control ensures that the portion of liquid refrigerant droplets at the inlet of the compressor is sufficient to keep the discharge line gas temperature below the allowed limit, while COP is kept as good as possible, following the strategy "As much as needed and as little as possible".

The discharge gas temperature limitation is compressor-type dependent.

5.2.3 Main superheat control

One bipolar expansion valve per circuit can be controlled by PeC for heating and cooling mode.

The superheat control is based on pressure/temperature control strategy involving a self-adapting PID control algorithm in order to adapt to different operating conditions. The main superheat setpoint is being adapted in a pre-defined range in order to achieve stable and optimal operating conditions.

NOTE: **To test the control behaviour at special conditions, fixed and non-adaptive PID parameters can be used in the "Manual Control mode". Please contact the Application Engineering department at Emerson in case this functionality needs to be configured.**

5.2.4 External capacity request via Modbus

The capacity request for **heating and cooling modes** can be sent by the system controller via Modbus communication. In addition to the capacity, the operating mode has to be set separately.

The capacity input request, sent via Modbus communication, is an absolute value expressed in %.

The maximum available capacity for the current operating conditions is accessible by the system controller via Modbus communication.

5.2.5 Start-up configuration function

During variable-speed compressor start-up, the compressor will run to the start-up speed with a given ramp-up rate. When the 4-way valve position is correctly set, the compressor will go to the mode-based start-up speed. The compressor speed is stabilized at the start-up speed for a given time (start-up duration). After that, the controller will modulate the speed to meet the capacity requirement of the system.

5.2.6 Compressor shutdown

If the controller receives a compressor shutdown command, it will switch off the fixed-speed compressor(s) first if it is (they are) running. Then the variable-speed compressor will shut down according to a pre-determined procedure.

5.2.7 Oil return function

To ensure sufficient oil level in the compressor at all times, the system has to be properly designed and qualified by the OEM. To qualify oil return performance of the system, Emerson can provide compressors with sight tubes.

All the parameters associated to the oil return function are configurable. If the compressor speed goes below a threshold value for a certain amount of time, the oil return function triggers. This function forces the compressor to an "oil return" speed for a brief period.

5.2.8 Maximum speed during heating

Maximum speed during heating restricts the speed of the compressor, to limit the load on it and the heating capacity of the system.

5.2.9 Speed control

The speed regulation algorithm is used in heating and cooling modes. The PeC calculates the speed that has to be applied to the compressor in order to match the requested capacity.

However, if the operating point reaches the lower limit of evaporating temperature, the compressor speed is decreased in order to stay inside the envelope.

When the condensing temperature reaches the upper limit of the envelope, the speed is also decreased.

5.2.10 Envelope limitations

To avoid overload of the compressor motor, the MOP function of the PeC limits the evaporating pressure to a pre-determined value, defined according to the safe operating envelope of the compressor(s). The evaporating temperature is limited by decreasing the main expansion valve opening causing higher superheat values.

The speed request has to respect the allowed envelopes according to the unit's operating point. This means that for the evaporating and condensing temperatures of the unit, the controller runs through all the envelopes of the compressor to find the lowest and highest envelopes containing the point.

The calculated envelope gives the minimum and maximum speeds allowed for the operating point. Note that for each limit, the controller progresses to refine the envelope (up to a precision of 50 rpm).

If the evaporating temperature of the unit goes around the left side of the largest envelope allowed (equivalent to 4500 rpm) or if the condensing temperature goes around the top side of the largest envelope, a smart control algorithm is implemented to attempt to bring back the unit's operating point inside the allowed envelopes. The resulting speed is not filtered but it is still bound according to the allowed envelopes.

5.2.11 Variable-speed Scroll smart crankcase heater function

The PeC controller uses a smart crankcase heating function to prevent the risk of liquid migration. It keeps the scroll temperature in a temperature band of 5-10 K above the evaporating temperature. The heater function is only active in "Standby" mode of the PeC. By using "Standby" and "Off" modes, the heater can be switched on and off by the OEM system controller.

This function is available only when there is one variable-speed compressor on the circuit.

5.2.12 FREMAR band protection (FREquency Management to Avoid Resonances)

Due to system design and the wide speed range of the compressor, harmful or disturbing resonance vibrations can occur in the mechanical system. If such resonances are measured during the OEM system qualification process and cannot be avoided, the Fremar band protection can be used to cut out the critical speed range(s) by defining the Fremar bandwidth and up to 3 separate frequencies.

5.3 Alarm management

5.3.1 "Alarm State" during compressor operation

Exceeding hard-programmed or configured operating limits leads to an alarm or warning to the alarm registers. Depending on the delay time and the different alarms and warnings, the system may continue to run.

The PeC will react, on a delayed warning or alarm, by changing the speed and valve opening to avoid getting into an "Alarm State". The OEM system controller can also trigger preventive actions by, eg, reducing demanded capacity, increasing pump speed, fan speed, etc.

If there is no delay time on an alarm or if the delay time has expired, the PeC goes into "Alarm" state. "Alarm" state means:

1. Compressor is shut down as fast as possible and valves will close accordingly.
   a. Alarm registers are copied as a snapshot into shadow alarm registers and cleared.
   b. Hardware and software alarm words are written to the alarm history.
   c. The alarm relay is activated (the relay status can be monitored via Modbus communication, "Read parameter").
2. After the alarm cause has disappeared, the application state goes into "Waiting" state (alarm pause) before a restart is attempted.
3. When the alarm pause time has expired, all the alarms, alarm shadows and relay/bit are cleared and the PeC goes back to normal operating mode.

NOTE: **For more information please refer to Technical Information TI_Sol_PEC_01 "Performance Controller PeC – Modbus Interface Description" or contact your local Application Engineering representative at Emerson.**

5.3.2 Hardware alarms

On occurrence of any hardware alarm, the system will shut down immediately. If not mentioned specifically, all hardware alarms are self-resetting and the system will restart when the alarm disappears and the forced waiting time (Alarm Pause) has expired.

- **Valve alarms:** A complete valve check is performed at start-up. This test is repeated on a valve if it has been detected as faulty. Upon regular operation, at the end of each valve movement, the energized coils are checked.
- **Sensor failures:** These alarms are evaluated permanently regardless of application state.
- **VSS & bipolar drive communication:** Every second the PeC reads the variables available from the bipolar drive unit and the VSS drive. After 5 successive failed attempts, the associated alarm will be raised and the associated data will be invalidated. Note that during the first four failures, the old values are kept.
  During HP alarm or EVU lock, the VSS communication alarm is disabled (drive is unpowered).
- **High-pressure switch alarm:** This alarm is raised whenever the digital input 2 is released. During HP alarm, the VSS communication alarm is disabled (drive is unpowered).
- **Compressor alarm:** This alarm is raised if there are major or minor faults on the VSS drive. The details of the compressor alarm cause are reported in the VSS fault structures.
- **EEPROM failure:** The EEPROM memory holding configuration parameters and energy counter values are checked at reset. This alarm is resettable only by power off – power on.
- **COM timeout:** When the analog input is not used on the controller, the communication to the system controller has a timeout of 60 sec. When this timeout expires, the compressor shuts down. When communication resumes, the system restarts in the state present on the write variables.

5.3.3 Software alarms

Delay counter triggers an "Alarm State" when configured delay time is exceeded			
Delay counter increases	Over limits	↓	Limit value
Delay counter stopped	Inside limits	Dead band	Limit value - Bandwidth
Delay counter cleared	Inside limits	↑	

Table 17: Dead band function on alarms

- **Low pressure alarm:** This alarm works in a dual fashion. If the pressure is above the threshold, the alarm is cleared.
- **Low superheat:** This alarm works in a dead band fashion with an incremental counter.
- **High superheat alarm:** This alarm works in a dead band fashion with an incremental counter and can indicate low refrigerant charge in the system.
- **Valve large opening:** Raised only as warning. This alarm works in a dead band fashion with an incremental counter and can indicate low refrigerant charge in the system.
- **High condensing pressure:** This pressure alarm is one of the system protection functions: when the maximum condensing pressure (adjustable) after a time delay (adjustable) is exceeded, the high condensing pressure alarm is triggered and the compressor is shut down to protect the system before the mandatory high-pressure switch triggers.
  This does not replace the high-pressure switch limiter imposed by EN 378.
- ***Freeze alarm:*** *This alarm is currently inactive. It will be implemented in future in order to protect the heat exchanger in cooling mode.*
- **Envelope Tc low:** Raised only as warning. This flag is raised if the condensing temperature is below the minimum allowed value. No preventive action is performed and the allowed time outside the envelope is 30 minutes.
- **Envelope Tc high**: Raised only as warning. This flag is raised if the condensing temperature is above the maximum allowed value. Compressor speed is decreased in order to stay inside the allowed application envelope.
- **Envelope Te low:** Raised only as warning. This flag is raised if the evaporating temperature is below the minimum allowed value. Compressor speed is decreased in order to stay inside the allowed application envelope.

- **Envelope Te high**: Raised only as warning. This flag is raised if the evaporating temperature is above the maximum allowed value. Valve opening is decreased in order to stay inside the allowed application envelope (MOP protection).
- **Envelope alarm:** The envelope alarm is triggered if one of Tc low, Tc high, Te low or Te high flags are raised for the respective durations. This alarm stops the system.
- **High discharge temperature:** This alarm is triggered immediately if the discharge temperature exceeds 130 ºC.

5.3.4 Machine alarms summary

Alarm description	Alarm Status	Inverter speed	Circuit 1 fixed-speed comp.	Circuit 2 fixed-speed comp.	Valve 1	Valve 2	System controller action
Any sensor failure **Inverter communication** **Oil sensing controller communication** **Inverter alarms** **Circuit safety 1, 2** **Power loss** **Valve 1, 2** **High discharge temp. 1, 2, 3, 4, 5, 6** **Low pressure 1, 2** **Low superheat 1, 2** **High superheat 1, 2** **High pressure 1, 2** **Envelope 1, 2** **Freeze protection 1,2**	Alarm	Shut-down	Switch off	Switch off	Closing	Closing	Force immediate system shutdown
Supervisor communication	Alarm	OFF	OFF	OFF	OFF	OFF	Force graceful system shutdown
Valve large opening 1,2	Warning	Normal control	Normal control	Normal control	Normal control	Normal control	
Envelope Tc low 1, 2	Warning (for 30 min.)	Normal control	Normal control	Normal control	Normal control	Normal control	
Envelope Te high 1,2	Warning (for 10 s)	Normal control	Normal control	Normal control	MOP control	MOP control	
Envelope Tc high 1,2	Warning (for 10 s)	Speed reduction	OFF (after 5 s)	OFF (after 5 s)	Normal control	Normal control	Can monitor these and take preventive action (increase fan or pump speed)
Envelope Te low 1,2	Warning (for 10 s)	Speed reduction	OFF (after 5 s)	OFF (after 5 s)	LOP Control	LOP Control	

Table 18

5.4 Energy metering

PeC provides information on system performance: power, COP, SCOP, SEER, heating and cooling capacity and minimum / maximum capacity.

PeC calculates the energy from compressors performance maps and values measured from the refrigerant cycle:

- Heating energy + electrical energy in heating mode
- Cooling energy + electrical energy in cooling mode

These values can be read once per second in Wh (2 X 16 bit).

Accumulated values for SCOP and SEER calculation are stored once every 24 hours in read-only registers. Resetting the PeC or a "power off" cycle will lead to a loss of non-stored information.

All these values can be accessed via Modbus communication.

For SCOP and SEER calculation, accessory power for fan, pump, etc. is included in the calculation (constant 150 W by default). Static accessory power can be pre-set, from 0 to 3000 W, on configuration parameter.

For greater accuracy, it is possible to give the actual accessory power consumption, eg, for variable fan, pump, etc. via Bus communication to the PeC, to be considered for SCOP and SEER calculation.

Variable accessory power has to be written to the "Accessory Power value" write register.

On PeC power up, the "Accessory Power" write register is initialized by the "Accessory Power" configuration parameter value.

5.5 Modbus protocol specifications

NOTE: **Please read carefully Technical Information TI_Sol_PEC_01 "Performance Controller PeC – Modbus Interface Description" to avoid system-controller communication problems and to be able to use the latest PeC features. If further information is needed, please contact your local Application Engineering representative at Emerson.**

6 Laboratory testing

6.1 Semi-manual mode

For lab testing purposes and/or to achieve special running parameters or conditions, it is possible to activate the semi-manual mode in heating or cooling mode. It is possible to change the control mode from automatic to manual on the compressor speed or the expansion valves, to get manual control over the device(s).

Heating/cooling capacity, compressor speed or valve openings are set as absolute values of kW, RPM or % valve opening.

Defrost can be activated and deactivated via push button registers.

NOTE: **The semi-manual mode is only available via Modbus communication and for experienced users.**

6.2 Manual mode

To test the system components attached to the PeC, it is possible to handle all active components manually.

No automatic function and no safety or alarm functions are active in this mode.

All components must be controlled manually, eg, for component function test.

To go into the manual mode, the "Analog command" must be deactivated ("Analog command inhibits" configuration parameter).

NOTE: **The manual mode is only available via Modbus communication and for experienced users.**

6.3 Starting lab testing with Modmonitoring software

To quick-start lab testing, Emerson provides a Modbus communication-based PC software with which all the PeC functionalities are available and the testing on the prototype can be performed.

NOTE: **For more information please contact your local Application Engineering representative at Emerson**.

6.4 Software update on the PeC

For lab testing purposes or during the qualification process, an update of the PeC firmware may be needed. To this end, Emerson can supply a programming tool and an instruction sheet about how to flash the new firmware on the PeC controller.

The PeC software may be updated via a Modbus cable through the "Modbus Slave" port.

NOTE: **For more information or to get the programming tool or instruction sheet, please contact your local Application Engineering representative at Emerson.**

7 Electrical connection

7.1 General recommendations

WARNING
Conductor cables! Electrical shock hazard! The controller operates at hazardous voltages which can cause severe personal injury or equipment damage. Extreme care and precautions must be taken when handling the product.
The controller must always be inserted inside an electrical panel that can only be accessed by authorised personnel. The keyboard must be the only part that can be reached. Insert the probe where it cannot be reached by the end-user.
Disconnect all the electric connections before performing any maintenance or servicing work.
The device must never be hand-held while being used.

CAUTION
Wrong supply voltage! Material damage! Verify that the power supply voltage is correct before connecting the controller.
Consider the maximum current that can be applied to each relay.

IMPORTANT
Make sure that the wires for the probes, the loads and the electrical power supply are separated and sufficiently distant from each other, without crossing or intertwining with each other.
Separate the power of the controller from the rest of the electrical devices connected inside the electrical panel. The secondary of the transformer must never be connected to the earth.
In the case of applications in industrial environments, it may be useful to use the main filters in parallel to the inductive loads.

During the installation process, follow the recommendations below to prevent the device from malfunctioning:

- Separate the cables of the analog inputs from those of the digital inputs, and the serial line cables from the power cables, to avoid malfunction due to electromagnetic interference.
- Separate the power of the device from that of other electrical components.
- Never connect the secondary of the supply transformer to the earth.
- Separate the signal cables from the power cables. It is recommended to follow the diagram in **Figure 13** below as far as possible.

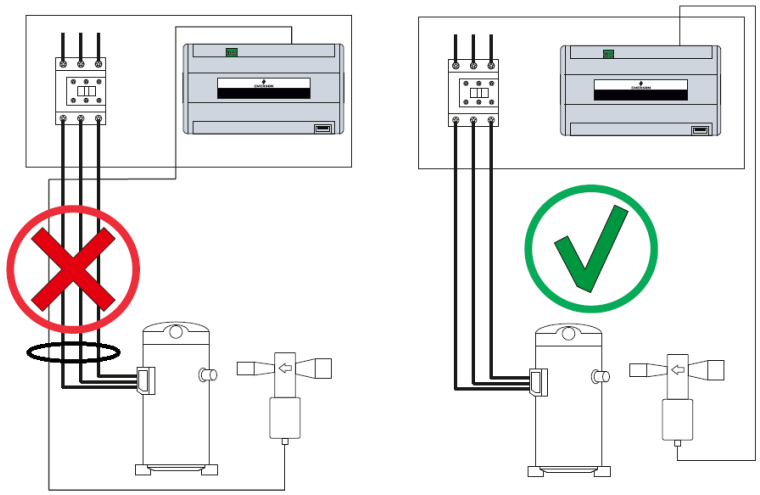


Figure 13: Example of wrong connection

The example in above diagram shows how improper connection can generate a wrong signal to the EXV valve and the possibility to lose steps.

7.1.1 EMC

- Separate drive-to-compressor supply from controls, sensor lines and communication lines.
- Keep a distance of 10 cm between clean and dirty lines and components if possible.
- Do not disable EMC measures by:
  - wrong mounting of components (position & orientation);
  - crossing or bringing together clean and dirty cables or components;
  - putting components too close together;
  - not keeping enough clearance distance.

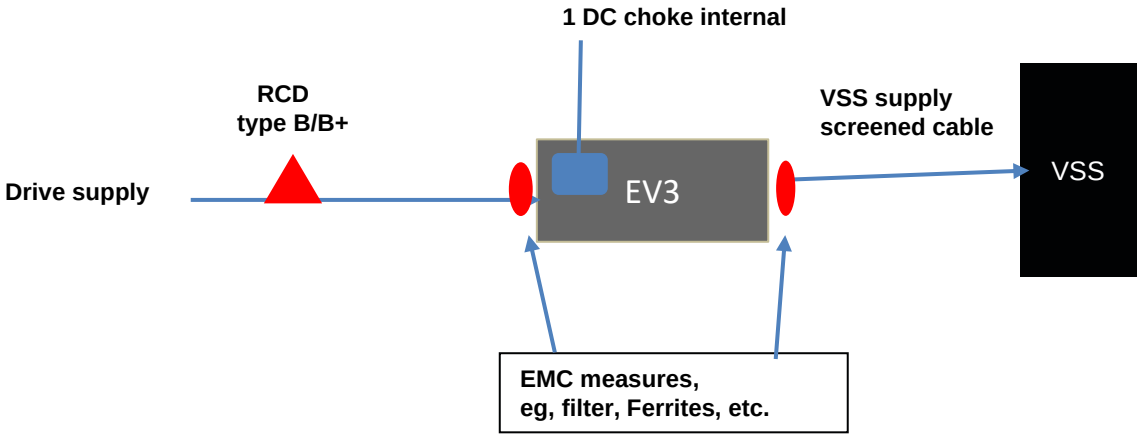


Figure 14

7.1.2 Ferrites

- Ferrites should be positioned close to input and output of the drive.
- Do not pass input and output wires which would make the ferrite useless.

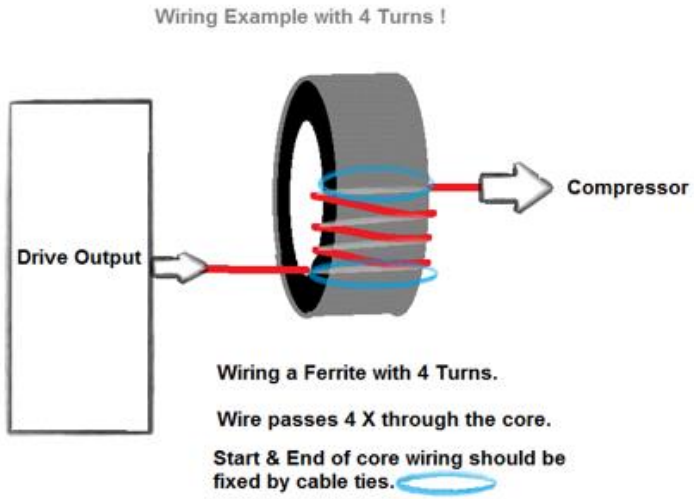


Figure 15: Example of good practice 4 turns with one ferrite

NOTE: **For more information, please refer to Application Guidelines AGL_Sol_EV3 "EV3 Inverter Drive for ZPV* Variable Speed Compressors" and AGL_AC_VS_YPV "Copeland Scroll Variable Speed Compressors for R32 Applications – YPV066* & YPV096*" or contact your local Application Engineering representative at Emerson.**

7.1.3 Digital inputs and outputs wiring

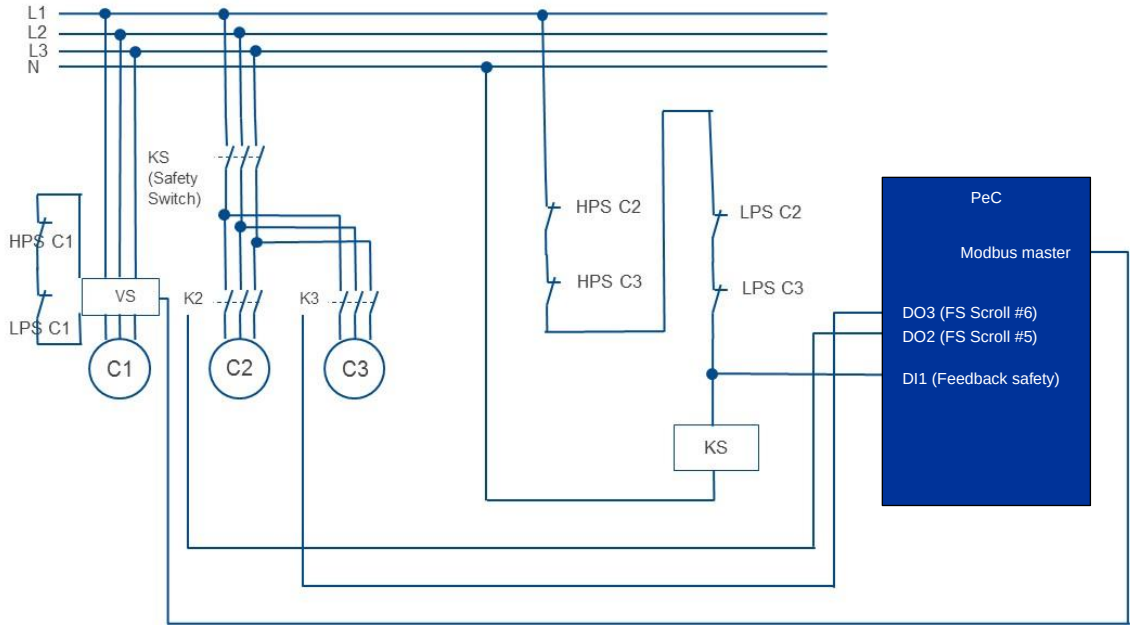


Figure 16: Digital inputs and outputs wiring for variable-speed circuit 1 (proposal)

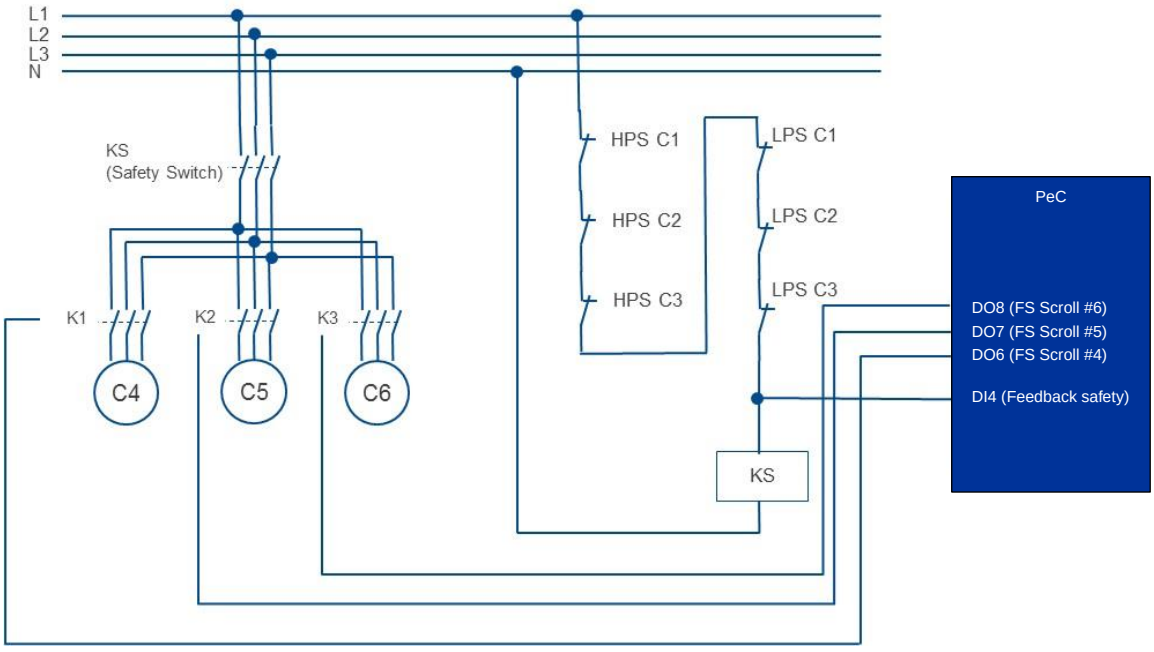


Figure 17: Digital inputs and outputs wiring for fixed-speed circuit 2

8 Items list for electronic solution package

Description	Type	Item number	
PeC series	PeC C100 (single circuit) PeC C200 (double circuit)	8418438 8418449	
Electronic expansion valves EX4 – 7 Bipolar stepper motor valves, uniflow	EX4-I21 EX5-U21 EX6-M21	800615 800618 800621	
Cable connector assembly	EXV-M60 (6-m cable)	804665	
Pressure transmitter Suction pressure 18 bar Discharge gas pressure 50 bar	PT5N-18M PT5N-18T PT5N-50M PT5N-50T *(Type: xxM = screwed, xxT = brazed)*	805351 805381 805353 805383	
Plugged cable assembly for pressure sensor	PT4-M15 (1.5-m cable) PT4-M30 (3-m cable) PT4-M60 (6-m cable)	804803 804804 804805	
Temperature sensor with	TP1 NP3 (3-m cable) TP1 NP6 (6-m cable) TP1 NP12 (12-m cable)	804489 804490 804491	
Accessories			
Connectors kit	PeC C100 PeC C200	807983 807984	
PeC – EV3 Drive Modbus connection	XJ485-USB converter	3185902	
PeC Firmware flash cable	Cable XJ485-USB converter	8416512	

Table 19

9 Certification & approval

- The controllers PeC C100 and C200 comply with the Low Voltage Directive LVD 2014/35/EU. The applied harmonised standards are:
  - EN 60335-1:2012/A11:2014: Household and similar electrical appliances - Safety - Part 1: Part 1: General requirements;
  - EN 60335-2-40:2003/A13:2012: Household and similar electrical appliances - Safety - Part 2-40: Particular requirements for electrical heat pumps, air conditioners and dehumidifiers.

  Other applied standards:
  - DIN IEC 60335-2-40:2018-05: Household and similar electrical appliances - Safety - Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers;
  - EN 60079-15:2010: Explosive atmospheres - Part 15: Equipment protection by type of protection "n".
- The controllers PeC C100 and C200 comply with the Electromagnetic Compatibility Directive EMC 2014/30/EU. The applied harmonised standards are:
  - EN 55014-1:2006/A2:2011: Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus Part 1: Emission;
  - EN 55014-2: 1997/A2:2008: Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus Part 2: Immunity - Product family standard.

  Other applied standards:
  - DIN EN 55014-1:2018-08: Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus Part 1: Emission;
  - DIN EN 55014-2:2016-01: Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus Part 2: Immunity - Product family standard.
- The controllers PeC C100 and C200 comply with RoHS 2011/65/EU, (EU) 2015/863.

10 Dismantling & disposal

With reference to the Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU and to the relative national legislation, please note that:

- **There lies the obligation not to dispose of electrical and electronic waste as municipal waste but to separate the waste.**
- **Public or private collection points must be used to dispose of the goods in accordance with local laws. Furthermore, at the end of the product's life, it is also possible to return this to the retailer when a new purchase is made.**
- **This equipment may contain hazardous substances. Improper use or incorrect disposal can have adverse effects on human health and the environment.**
- **The symbol shown on the product or the package indicates that the product has been placed on the market after 13 August 2005 and must be disposed of as separated waste.**
- **Should the product be disposed of incorrectly, sanctions may be applied as stipulated in applicable local regulations regarding waste disposal.**

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